

THE CHARACTERIZATION OF THE KEMPTON MINE COMPLEX, MARYLAND AND WEST VIRGINIA, USING GIS TECHNOLOGY

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ABSTRACT

Acid mine drainage (AMD), a legacy left by pre-law coal mining (prior to the 1977 Surface Mine Control and Reclamation Act), affects miles of western Maryland waterways, including the headwaters of the Potomac River. Prior to degradation, the North Branch of the Potomac River (North Branch) supported one of the largest trout and bass fisheries in the eastern United States. The Kempton Deep Mine Complex (Kempton) is the main source of AMD impairment in the North Branch. Kempton covers more than 12 square miles, or 7,680 acres, and discharges an average of five million gallons a day of acidic water into Laurel Run, a tributary that enters the Potomac River. Since 1994, the State of Maryland has maintained six lime dosers to neutralize AMD along more than 32 miles of the mainstem of the North Branch. Trout are stocked annually and populations of native fish and macro-invertebrates have returned to the river. In 1998, the Maryland Bureau of Mines began investigating whether a more permanent technology than in-stream dosing could solve the AMD problems of Kempton. A comprehensive, in-depth investigation of the Kempton Mine and surrounding area was conducted and developed into an accurate, detailed geologic/topographic map and technical database. Geographic Information System (GIS) technology was determined to be the best approach to store, view, and evaluate the large quantities of data and information. The Kempton GIS mapping and database includes numerous features that affect and impact the Kempton discharges in Maryland. The Kempton GIS has proven to be an invaluable tool to evaluate alternative AMD remediation technologies and was developed using ESRI Arcview and its extensions, Spatial Analyst and 3D. The GIS includes all data and maps collected in the study in an easily viewed format.

KEMPTON MINE COMPLEX OVERVIEW

The Kempton Mine Complex (KMC) is an underground deep mine located in the southernmost tip of western Garrett County, Maryland and extending southwest into West Virginia (Figure 1). Henry Gassaway Davis founded this mine complex. It operated as the Davis Coal and Coke Company from 1886 until 1950 and grew to encompass 12 square miles of interconnected underground workings in the Upper Freeport coal seam. The development of this mine complex began as nine smaller mines scattered amongst six small mining towns, one of which was

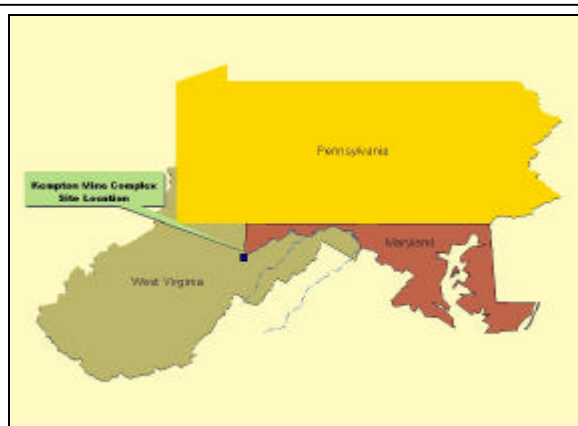


FIGURE 1 - GENERAL LOCATION OF THE KEMPTON MINE COMPLEX

Kempton, Maryland (Kempton). Between the years 1914 and 1950, approximately 650 people resided in Kempton using the mine as their primary means of support.

The Kempton portion of the mine began operations in 1914. Access to the coal was obtained through two deep mine shafts that extended 420 feet into the earth. These shafts, known collectively as Mine #42, entered the Upper Freeport at one of the lowest points of a plunging syncline. Gravity carried the water to the lowest point of the complex and pumps were then used to remove it. As the entire mine complex slowly grew, engineers were forced to deal with more water problems.

In 1950, operations ceased throughout the entire complex, as did the pumping of the water. Water built up within the void spaces of the mine and began discharging acid mine drainage (AMD). Nine AMD discharges were located in Coketon, West Virginia and drained into the North Fork of the Blackwater River, and two discharges appeared north of Kempton. By 1952, AMD north of Kempton became a major polluter to the North Branch of the Potomac River (North Branch). The North Branch is a branch of the Potomac River, a designated American Heritage River, and a major tributary to the Chesapeake Bay. The Maryland discharges from an abandoned Airshaft and Power Borehole which were used when the mine was active (Figure 2) and flows directly into Laurel Run, a tributary of the North Branch. Flows range from a minimum of one million to a maximum of six million gallons a day (mgd). In 1988, the State of Maryland began to investigate the abandoned mine complexes' impacts to the river as well as to develop a strategy that could remediate and/or abate these problems.

PROJECT OBJECTIVES

Maryland Department of Environment, Bureau of Mines (Bureau) and Maryland Department of Natural Resources, Power Plant Research Program (PPRP) launched the KMC Project in cooperation with the State of West Virginia and private industry in 1998. The overall objective was to restore the quality of the North Branch by reducing the impact of AMD discharging from the Airshaft and Borehole locations to the North Branch by “1) improving the quality and/or reducing the quantity of recharge to the deep mine and/or 2) improving the quality of the discharge from the mine pool” (Maryland Department of Environment, Water Management Administration, Bureau of Mines Environmental Protection Agency 104(b)(3) Grant #X983070-01-0). A Geographic Information System (GIS) would be developed to aid scientists in understanding the mine structure and the hydrogeology. “The visualization and computational capabilities of GIS enhance our ability to conceptualize the geometry and hydrology of the deep mine complex” (Hayes, Meiser, Lyons, pg. 1). In 1998 the Bureau was awarded \$225,000 from the United States Environmental Protection Agency (EPA) for Clean Water Act Section 104 (b)(3) monies to develop the *North Branch Potomac River Watershed Restoration Project: Investigation and Definition of the Geologic/Topographic Structure and Hydrology of the KMC*. The funding of this project allowed Bureau personnel and supporting organizations “to conduct a comprehensive, in-depth investigation of Kempton and

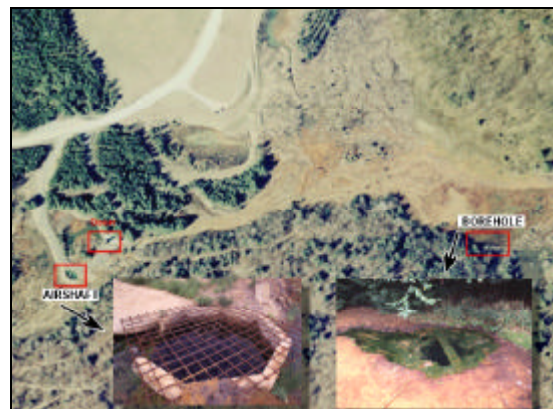
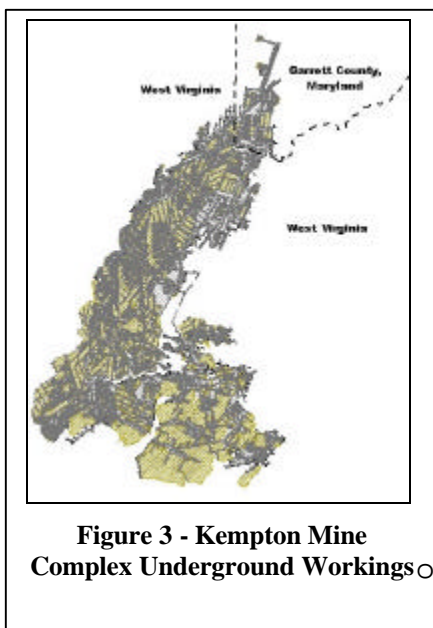


FIGURE 2 - KEMPTON, MARYLAND AMD INTO LAUREL RUN

the surrounding area” by compiling “an accurate, detailed geologic/topographic map of the entire deep mine complex and surrounding area of features that may have the potential to affect and impact the Kempton discharges, a detailed hydrogeologic report and a GIS that includes all data, maps, and relevant information tied in the course of the study, and an investigative report that evaluates and interprets the data and offers preliminary findings towards meeting the goal of reducing the acid load from the Kempton Mine” (Maryland Department of Environment, Water Management Administration, Bureau of Mines Environmental Protection Agency, Region 3, 104(b)(3) Grant #X983070-01-0).

GIS DEVELOPMENT

A crucial component in building a GIS is data collection. Detailed digital mapping (Figure 3) of the entire underground complex was provided to the Bureau by Western Pocahontas Properties, Inc. After geo-referencing this coverage to digital topographic maps, field technicians went out to the area to conduct a thorough investigation of the complex as a whole. Elements of this investigation consisted of the following:



- Baseline monitoring that included identifying and monitoring mine seeps, areas of water infiltration, and precipitation data;
- Mapping the topography, geology, and mine workings in and around the KMC including abandoned mine features such as high-walls and subsidence;
- Compiling the KMC history concentrating on areas such as water problems, drainage patterns, areas of weak mine roof, and ventilation schemes;
- Characterizing the stratigraphy and geologic structures for lineaments and fractures natural and resulting from mining;
- Defining the hydrogeology of deep mines, surface mines and surrounding areas;
- Identifying the relationship between the Upper Freeport and any overlying coal seams;

Investigating the mine and overburden geochemistry and identifying sources of alkalinity and acidity that could be contributing to the mine pool’s chemistry.

To accomplish these goals, technicians began compiling a vast amount of information. Weirs were installed at all eleven discharges (2 in Maryland, 9 in West Virginia) for regular baseline monitoring. Data from National Oceanic and Atmospheric Administration (NOAA) regional precipitation stations were obtained for comparison to the discharge levels to monitor recharge patterns. Flows were taken at all streams located throughout the KMC. Any stream that exhibited a loss was monitored on a regular basis to help identify potential surface water infiltration to the mine complex. Regional core log and coal seam data was obtained from West Virginia Geological and Economic Survey (WVGES) and many historic mine maps and records were obtained through The New Historic Society of Thomas, West Virginia. The West Virginia Department of Environmental Protection provided the Bureau with access to all recent and past problems associated with mining in the area of interest. PPRP funded the flying of low-altitude orthophotography during spring 1999, the development of topographic coverages, and the

production of hyperspectral imagery throughout the KMC. All information was incorporated into a stand-alone GIS for analysis and review. The GIS development effort was initiated in FY1998 with the final version projected for completion and submittal to the EPA by December 2002.

GIS UTILIZATION

The GIS proved to be a valuable tool in the analysis of the KMC. Spatial relationships and trends can be more easily identified using the modeling tool with various data. “Three-dimensional stratigraphic [models] and isopach maps help identify hydrogeologic features such as stratigraphic pinch outs, changes in dip, and mine pool barriers” (Hayes, Meiser, Lyons, pg. 2). Organized databases can be integrated into a GIS so that coverages in the forms of points, lines and polygons can be developed. The organization chose to use ArcView® Version 3.2 in conjunction with the Spatial Analyst and 3D Analyst extensions for the GIS platform.

The first phase in the development of the GIS was to characterize the geology of the mine complex in orientation to overlying and surface features. Specific areas of interest were the “regional geologic structure of the coal seam; [the] precise locations of underground mine workings; [the] degree of coal extractions; [the] locations of coal outcrops; and [the] proximity to overlying coal seams that have been mined” (Hayes, Meiser, Lyons, pg. 3). Using the geo-referenced digital mine layer and the detailed structure contours for the Upper Freeport coal provided by WVGES, it was possible for GIS technicians to create a 3-dimensional model of the workings to depict their true orientation and to help identify any remaining coal barriers that still exist within the KMC and the coal elevation to which it extends (Figure 4). This digital 3-dimensional model also helped guide scientists in predicting flow patterns and paths throughout the mine workings. The Bakerstown coal seam lies approximately 180-200 feet above the Upper Freeport coal seam and was also extensively mined. Structure contours and mine extents for the overlying Bakerstown coal were draped on this model and coal outcrop lines for both seams were digitized and plotted.

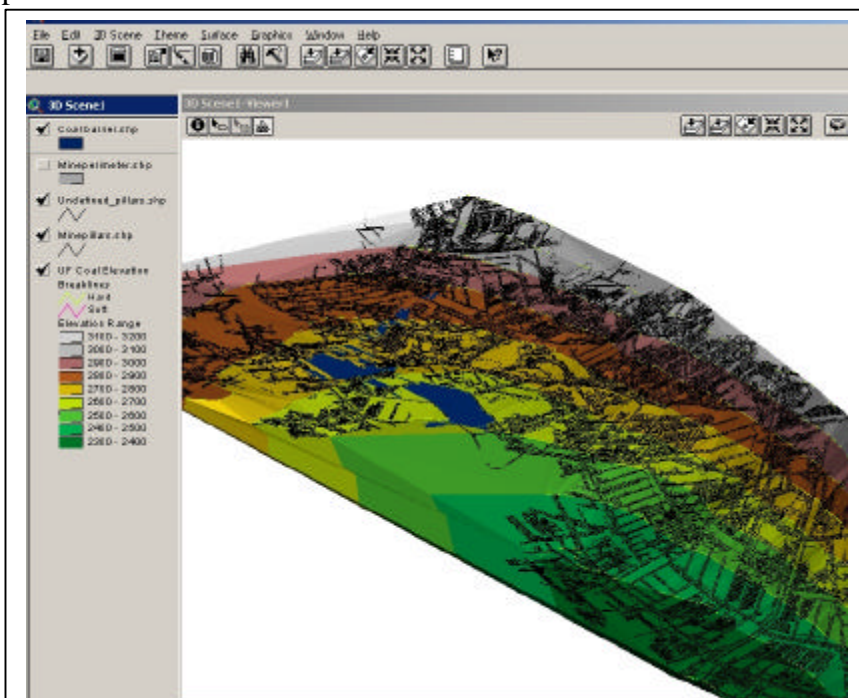


Figure 4 - 3-Dimensional Model

After the geologic visualization of the KMC complex was completed, the ability to look for hydrologic relationships between the underground mine and its overburden was enhanced. Using GPS positions of all the AMD discharges from the complex, elevations were established for the discharges at both ends of the complex. These elevations are representative of the pool

elevations in the underground complex. Once the elevations of the discharges were known, they were compared to the elevation of which the coal barrier extended and it was determined that two separate mine pools must exist within this underground complex. Plotting these points onto the KMC model allowed a GIS technician to extrapolate the pool coverage as it would exist in the mine (Figure 5) and calculate the total area of flooding in each pool (Table 1).

Table 1: Characteristics of the portion of the Kempton Mine Complex Underground Pool Flowing to Maryland and Impacting the North Branch of the Potomac River

Pool Name	Discharge Elevation	Total Area of Recharge (acres)	Portion of Area Flooded (acres)	Percentage of Flooding	Average Flow GPM
Kempton Pool	2652	5100	1890	35%	2700 GPM

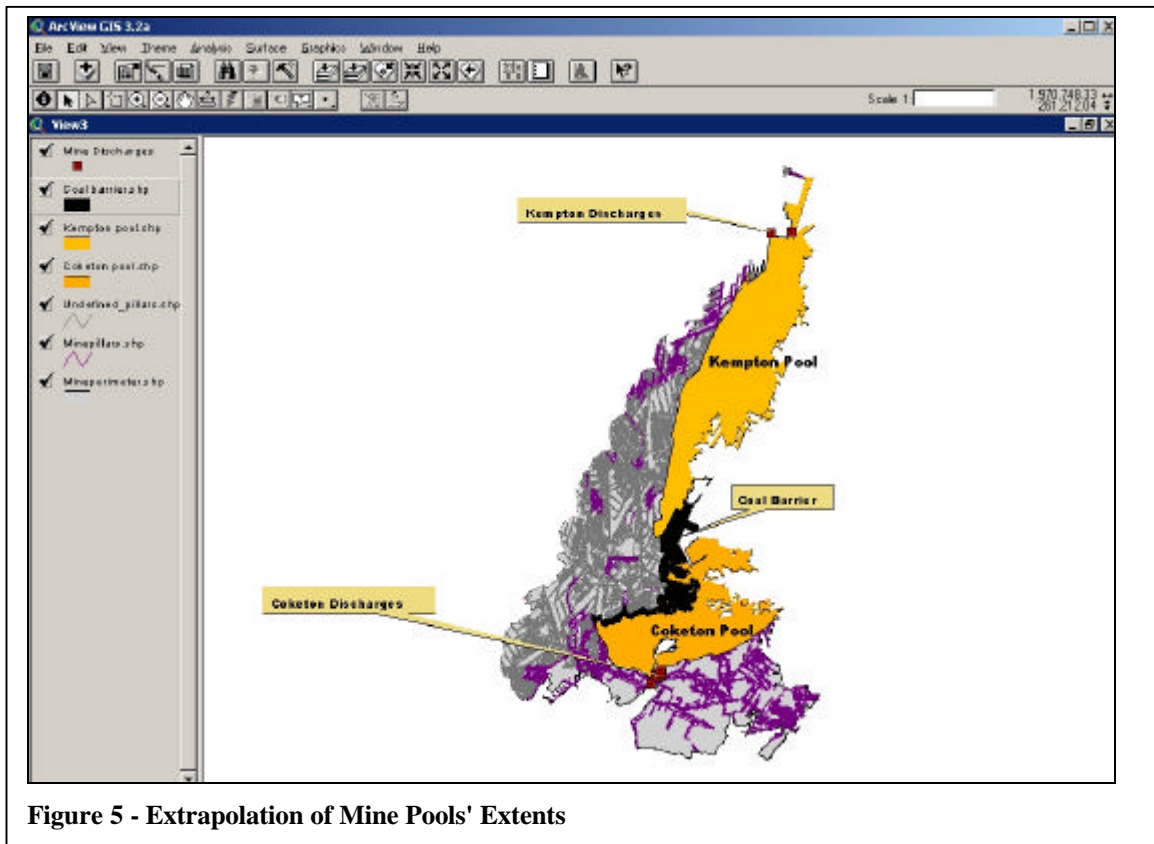


Figure 5 - Extrapolation of Mine Pools' Extents

Flows that were taken at the weirs were plotted against daily precipitation data collected from surrounding NOAA monitoring stations. These plots appeared to show a direct correlation of increases in discharges to rainfall events. Using a GIS buffering function, a buffer zone of 50 feet was calculated around both the coal outcrop and the streams (Figure 6). The intersection of these calculated 50-foot buffers were highlighted and used to determine specific areas of concentration for field personnel. Streams that exhibited losses at these targeted zones were part of a routine sampling plan. Flows were taken above and below the outcrop/stream intersection zones at three streams that show signs of loss on a regular basis.

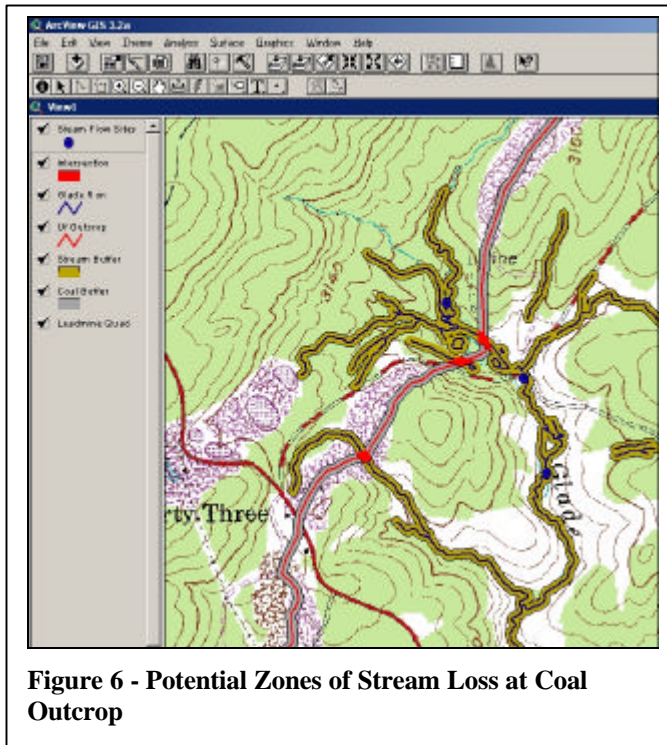


Figure 6 - Potential Zones of Stream Loss at Coal Outcrop

Another topic of interest pursued when examining the interconnectivity between the mining complex and the surface water was in areas that show evidence of subsidence on the ground surface. Using the GIS Spatial Analyst extension, technicians used ground elevation and coal elevation contour shape files to produce grids of the spatial coverage. Grids are raster-based data that store a numeric data value for each cell useable during analysis and calculations. These grid-projected elevations were subtracted from one another to produce a depth-to-coal layer. This layer helped technicians identify areas of shallow overburden throughout the KMC that could be affected by subsidence. Thickness maps were produced and taken to the field for reconnaissance of the

suspected areas. Large plots of area that exhibited the classic signs of subsidence (terrain features uncommon to the area, out-of-place depressions, odd vegetative disturbances) were GPS'd and plotted onto the thickness layer for review (Figure 7). All of the areas plotted fell within the tolerance range to be considered possible subsidence of the overburden into the KMC.

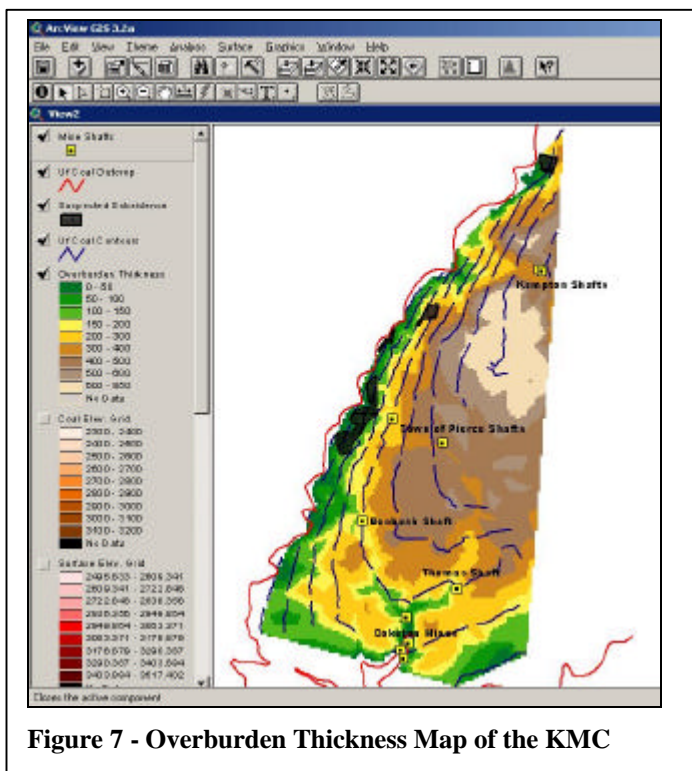


Figure 7 - Overburden Thickness Map of the KMC

COMPLEXITY OF DEVELOPMENT

The complexity of the development of this GIS involved many steps and many organizations. The Bureau worked with the EPA, PPRP, and WPP to investigate this problem. Bureau and PPRP employees worked with individuals at Frostburg State University, Geospatial Research Group (GRG) on a regular basis to conduct field studies and collect all possible field data needed to launch this project. Meiser and Earl, Inc. and Dr. Benjamin Hayes from Bucknell University provided the Bureau with the initial development of the GIS technology using ArcView® 3.2 and the extensions 3D and Spatial Analyst. GRG employees used the basic GIS and built it into a working system as described in the EPA work plan.

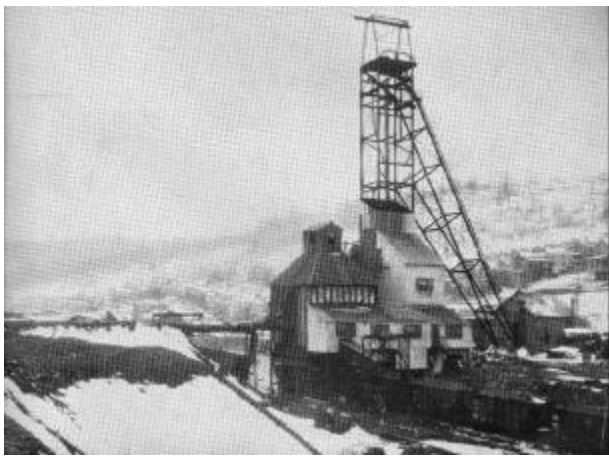


Figure 9 - Kempton Mine Tipple

forms of data are historic mine photos (Figure 8), old and GIS generated maps, digital aerial photography (Figure 9), and water quality data collected at the weirs and in the streams.

The Bureau refined the GIS produced by GRG and worked with Meiser and Earl, Inc. and Hughes-Martin Ink to finalize the product into an organized, powerful tool for the visualization and the analysis of the KMC. The structure of the GIS was built in a logical system of nine files that contained numerous folders: Base Map Features and Images (37 folders), Drill Logs (4 folders), Geology (30 folders), Hydrology (53 folders), Layout Boundary (1 folder), Mining (52 folders), Project Images (0 folder), Project Posters (0 folder), and Water Quality Tables (4 folders). This filing system was used to break up the information into general topics and then break down those

The GIS was built to provide users with the capabilities to analyze and model using “real” field collect information. Examples of the many

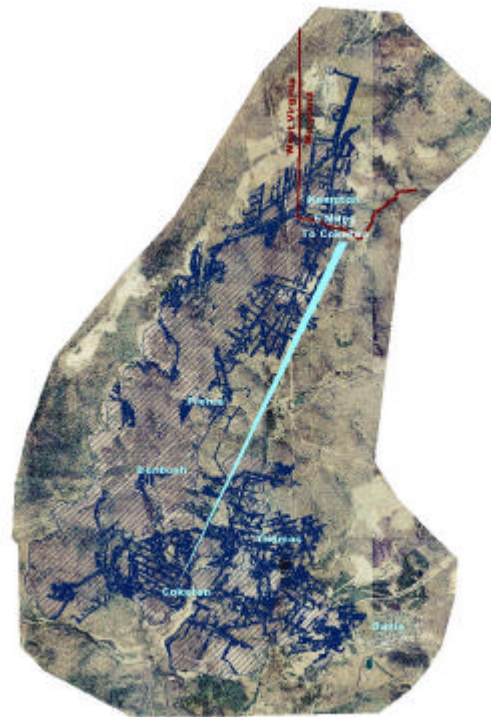


Figure 8 - Kempton Complex Aerial Photography

topics into reasonable folders of similar information. Not only is the information organized, but also a user has the capability to navigate throughout the GIS in a logical and systematic way.

Throughout this project, the GIS proved to be an extremely powerful tool in both the visualization and the analysis of the KMC. Without all the cooperating parties it is unlikely that this project would have come together as well as it did. As expected in a project this size, problems did arise bringing the information together. However, with the commitment of all participating individuals to complete the work, the project has been a remarkable success.

REFERENCES

Hayes, Benjamin R., Meiser, Edgar W., and Lyons, Constance, "Characterizing the Hydrogeology of the Acid Mine Discharges from the Kempton Mine Complex, West Virginia and Maryland." Paper presented at the North Branch of the Potomac River Symposium, Frostburg, Maryland, October 1999.

Lyons, Constance, "North Branch Potomac River Watershed Restoration Project." Maryland CWA Section 104 (b)(3) FFY99 Grant Work Plan submitted to the United States Environmental Protection Agency, Region III, May 1999.